A Tidal Habitat Restoration Success Story—The Union Slough Restoration Project

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[Editor's note: Tables, Figures and Photographs for Houghton et al. appear at the end of this paper.]

Abstract
In February 2001, dikes were breached to restore tidal circulation to a ± 20-acre, former agricultural parcel along Union Slough in the lower Snohomish Estuary, near Everett, Washington. Before dike breaching, an internal dike was constructed to protect Interstate 5 (I-5) and the site was graded to provide desired elevations for brackish marsh development. Finally, we excavated a deep dendritic channel that would allow maximum accessibility by juvenile salmonids and possibly Dungeness crab.

Substantial numbers of small invertebrates and fish were observed using and feeding in the site as early as the April following dike breaching. Summer and fall seining demonstrated use by six species of juvenile anadromous salmonids, with chinook and coho juveniles remaining in the site through November 2001. Benthic productivity appears to be high and a variety of shorebirds and waterfowl have been observed. Marsh vegetation has rapidly colonized elevations between about +7 and +11 feet mean lower low water, covering over 3 acres of the site by late summer 2002. Several pieces of large woody debris were recruited to shorelines within the site during winter 2001 – 2002 flooding, and most have remained. This and several other sites in the Snohomish Estuary clearly demonstrate that breaching dikes to restore tidal action is a relatively certain and often low-cost means of providing real and immediate increases in habitat function.

Introduction
The Union Slough restoration site was designed and built as compensation for improvements at the Port of Everett, Washington's marine terminal facilities (Figure 1). Both the project site and the Port's marine terminal lie at the mouth of the Snohomish River, the second largest drainage system entering Puget Sound. The Snohomish River supports runs of four species of Pacific salmon as well as anadromous steelhead, cutthroat, and bull trout. The estuary consists of four major distributary channels, of which Union Slough is the smallest. Tidal marshes and forests throughout the estuary were diked and drained for agriculture early in the last century, resulting in a loss of approximately 70 percent of the original off-channel habitat. Restoration of these habitat types is a primary focus of salmon recovery efforts in the watershed.

Over the last 40 years, intentional and natural breaching of dikes in various portions of the estuary have restored nearly 400 acres of formerly diked lands to tidal action (North Ebey Island, Middle Ebey Island, Mid Spencer Island, Marysville Sewage Treatment Plant Mitigation, South Spencer Restoration; see City of Everett and Pentec 2001). Where this has occurred, natural site evolution and vegetative succession have resulted in excellent-quality habitats and high ecological function (City of Everett and Pentec 2001; Cunningham and Polayes-Wein 1995; Cordell et al. 1998, 1999; Jones & Stokes 1999a, 1999b, 1999c). In this paper, we describe the background leading to the construction of the most recent of these dike removal events, the Union Slough restoration project. We also present the findings from the inspections and monitoring programs conducted through 2002 and summarize the status of mitigation credits remaining in the site. All work described was funded by the Port of Everett through an environmental services contract with Pentec Environmental.

Background

Project Description
The Port of Everett defined a program to improve its marine terminal facilities in two stages over a 10-year period. Stage 1 of the marine terminal improvements (MTI) consisted of a series of coordinated actions to:

- Deepen existing berths.
- Clean up contaminated sediments between Piers 1 and 3
- Construct a new deep-water berth with >6 acres of cargo marshalling area south of Pier 1.
- Use contaminated sediments from between Piers 1 and 3 as fill for the new berth and cargo marshalling area.

These actions resulted in the following:

- Removal of contaminated sediment, wood waste, and other industrial debris from 17.8 acres of bottom, thus improving habitat for Dungeness crab, demersal fish, and other benthic fauna.
- Net loss of 9.4 acres of littoral marine habitat (above –8 feet mean lower low water, MLLW) by filling and dredging; net gain of 3.5 acres in deeper-water habitat by dredging.
- 1,000 feet of riprap slope of 2h:1v replacing 1,400 feet of vertical bulkhead shoreline.

Pentec (1996) developed the following mitigation plan for a Port-owned site on Union Slough to compensate for the unavoidable loss of ecological functions in the MTI project area:

- Construct a new dike along the I-5 right of way.
- Excavate a dendritic drainage pattern within the field between the existing dike and the newly constructed dike.
- Breach a portion of the existing dike to allow development of an intertidal saltmarsh/mudflat/drainage channel complex (Figure 2).

Project Objective

The objective of the Union Slough mudflat and saltmarsh restoration was to provide estuarine habitat and ecological functions to replace those lost to unavoidable impacts of the Stage 1 MTI and to provide advanced mitigation credits to offset future unavoidable impacts of Port development activities. This objective was to be accomplished by breaching the existing dike to restore tidal circulation to an area that had been diked and used in agricultural production for many decades. Depending on elevation, the farmland was expected to provide intertidal mudflat or saltmarsh and to provide high-quality habitat for juvenile salmon and shorebirds. Tidal channels were to be sculpted into the fields before the dikes were breached and deeper portions of these channels were expected to provide habitat for Dungeness crab (*Cancer magister*).

Union Slough Design

The Port of Everett purchased the 29.2-acre Union Slough site land for the purpose of providing mitigation for planned Port developments. Lands adjacent to the site to the east are owned by the Washington Department of Transportation (DOT); I-5 is located on those lands. Union Slough is adjacent to the site on the west (Figure 2). A dike was originally built near the slough in the early part of the 20th century and the land drained for agricultural use. The land was farmed through the 1990s, although construction of I-5 had isolated the site from the larger portion of Biringer Farm to the east. In 1996, the site consisted of 18 acres of farmed land in the northern portion, a palustrine emergent wetland of approximately 5 acres in the southern portion of the property, and a 1.77-acre blackberry-lined pond along the northern edge of the site (Photo 1). North of the pond and the restoration site are approximately 15 acres of largely unused lands with some recent fill; this area is bisected by a gravel road accessing Biringer Farm.

Proposed Design

The proposed construction plan for the site was expected to create a minimum of 24 acres of habitat below extreme high water (+14.5 feet MLLW). A minimum of 2 acres of the site was to be in channels excavated to +2 feet MLLW or deeper. The freshwater pond would be reduced in size to approximately 1 acre, and the pond area within the new dike would create a pool within the site. An additional component to this mitigation project was to provide education to the public. A visitor access and viewing area was to be constructed at the north boundary of the created marsh/wetland complex. Parking was to be provided for at least five cars. Vandal-resistant signs were to be posted describing the nature of the project and the expected natural succession of area vegetation, and identifying the wildlife and aquatic life that use the area.

Construction and Design Modifications

Several changes were made to the plans prior to construction, for the following reasons:

After over a year of discussions, agreement could not be reached for DOT participation in the project. Since DOT would not allow the new dike to be built on its property (as the bed for a new southbound lane of I-5), approximately 4 acres of the restoration site were required for construction of an independent dike (Figure 2).

The entire freshwater pond was left intact because listing of Puget Sound salmonids as threatened under the Endangered Species Act had occurred between the time of the permit issuance (1996) and the time when construction could finally begin in 2000. The U.S. Army Corps of Engineers (Corps) required consultation with the National Oceanic and Atmospheric Administration (NOAA) Fisheries and the U.S. Fish and Wildlife Service regarding the potential adverse effects of construction of the tidal restoration project on listed species. The Corps further restricted the Port from disturbing wetlands inside the dikes until the consultation was complete. Thus, construction of the north dike across the palustrine open-water pond could not begin until at earliest February 2001. Since breaching could not occur after February 15 due to inwater work restrictions, the Port elected to construct the north dike along the south side of the pond so the project would be completed in time for the spring 2001 outmigration of anadromous salmonids.

As constructed, the site has provided an area of 19.3 acres (rather than the 24 acres anticipated) of new tidal habitat below extreme high water. The new dike is 3,700 feet long with a crest elevation of +16.1 feet MLLW (Figure 2, Photo 2). The dike protects the highway embankment and Port property to the north from the 100-year flood. A portion of the material for this dike was excavated from the site to form the drainage channels; additional material was brought in from off site. Elevations around the margins of the central mudflats and channels were established within the range (approximately +9 to +13 feet MLLW) where saltmarsh vegetation can be expected to establish. Elevations above approximately +10 feet MLLW were hydroseeded following construction to stabilize newly shaped slopes. The combination of tidal flooding and brackish water conditions was expected to exclude invasive exotics such as purple loosestrife and reed canarygrass from the marsh below the high tide line. Following completion of the site work inside the dikes, approximately 60 days were allowed for the new dikes to stabilize before the outer dike was breached. The existing dike along Union Slough was breached during a low tide series on the evenings of February 6 through 9, 2001.

Monitoring Program

General Requirements

A 10-year monitoring program was established for the site in the mitigation plan (Pentec 1996; Table 1).
Year 0 (2000) included construction of the new dike, site grading, and channel excavation. Construction was completed in Year 1 (2001) with the breaching of the dike in February.

Construction Monitoring

Following breaching of the outer dike in early February 2001, water from Union Slough filled the new mitigation area. Effects of dike breaching on water quality in Union Slough downstream of the breach were measured in the morning of February 8, 2001, the first time when tidal waters drained from the site following its initial flooding. A plume of water leaving the site along the immediate downstream shoreline was visibly more turbid than the ambient water in Union Slough. Measurements showed that this plume had approximately 21.8 NTU while Union Slough water had 8.9 NTU of turbidity. The plume was measurable for approximately 21 meters (70 feet) downstream of the breach and extended about 5 meters (15 feet) off shore.

Qualitative Observations

We briefly observed the use of the area by waterfowl and salmon on March 11, 2001. Several species of waterfowl were observed, including Canada geese. No juvenile salmon were seen, although this was not unexpected; earlier surveys of juvenile salmon presence in the estuary had found only limited numbers of juveniles this early in the outmigration season (Pentec 1992). On April 7, 2001, exactly 2 months after the site was first flooded, much of the mud bottom was covered with a thin brown diatom film that partly lifted to the water surface as the tide rose. Large mysids were common in very shallow water along the shorelines of the site. During the 3 hours that personnel were on the site for the planting, three species of shorebirds were seen feeding along the shorelines within the site: two killdeer, a yellowlegs, and a flock of about eight peeps. Geese and unidentified ducks were also seen inside the dikes. A red-tailed hawk and a juvenile bald eagle were seen flying overhead. Juvenile salmon were abundant and widely distributed along shallow water shorelines within the site. Most of the fry observed were small and were most likely chum salmon. A single larger fish, possibly a chinook, was seen jumping out of the water. Juvenile salmonids were seen in all of the constructed channels, including the southern boundary of the flooding main channel where the rising tide met the still actively draining flow from the southernmost reaches of the site.

Brief site visits were conducted in May to assess revegetation of excavated areas and to observe other ecological activities. Photopoints were established to allow time series photography documenting vegetative succession (Photos 2, 3, 4). In May 2001, areas that had been hydroseeded were beginning to be covered with new grasses. Some banks were developing areas of marsh plants through natural recolonization. Many of the cuttings installed in April (see Revegetation Program, below) were growing. Numerous schools of small salmonid fry (chinook or chum) were seen holding in the strong current flowing out of the main channel during a falling tide; many were feeding at the surface. Small schools (about 5 to 20 fish) of salmon were especially dense in shallow waters in and adjacent to the central channel in the southern half of the site. Larger smolts (approximately 80- to 120-mm fish, probably chinook) were jumping (feeding) in deeper waters over the channels. In shallow water along the shore of the site, numerous large amphipods and a few isopods were present.

Site visits during the summer of 2001 tracked the development of riparian vegetation planted in April. Other species seen on or over the site included red-tailed hawk, great blue heron, glaucous-winged gull, killdeer, spotted sandpiper, blue-winged teal, osprey, Canada goose, belted kingfisher, song sparrow, barn swallow, and black-tailed deer (tracks).

Pentec visited the site on December 23, 2001, following a period of significant early winter storms and high water. Wave action generated by southerly winds during high water had caused erosion of 15 to 25 cm of sediment from the south face of the north dike and eroded a substantial area of marsh plants that had colonized the area. High water had delivered large quantities of small and large woody debris (LWD) that had deposited along the north and northeast shore of the site. LWD included a 30-m-long cottonwood tree with root wad that had grounded on the upper eastern shore of the site. No fish were seen but amphipods were abundant in shallow water along the shoreline. Two dunlins were present feeding along the water's edge.

Revegetation Program

Although not required by the mitigation plan (Pentec 1996), we decided to accelerate the development of riparian vegetation. On April 7, 2001, Pentec staff harvested riparian vegetation from higher elevations along the South Fork of the Stillaguamish River. It was decided to harvest cuttings from this area because of the desire to obtain plants that had not yet begun to develop leaves and catkins. Willows at this site had broken bud, and catkins were beginning to form on lower-elevation stalks. Approximately 200 cuttings of willows (*Salix* sp.) and other species were taken from sand bars up the North Fork of the Stillaquamish River valley. About 200 willow whips ranging in length from about 0.6 to 1 m were cut with shears. About six willows, six salmonberry (*Rubus spectabilis*) plants, and four red alders (*Alnus rubra*) were extracted from the bar with roots intact. In addition to the cuttings and rooted plants harvested, 160 rooted plants were obtained from a local nursery (Table 2).

All of the above plants (approximately 360 rooted plants and cuttings) were planted on April 7, 2001, by a crew of about 10 people. Willow cuttings were inserted into the soil of the dike just above the high tide line in groups of two to four cuttings, separated by approximately 6 to 10 m. Within each group, plants were placed approximately 1 m apart. Other species were spaced by 3 to 10 m on the upper slope of the dike between the high water line and the dike crest. Sitka spruce (*Salix sitchensis*) trees were planted on lower portions of the dike and Douglas firs (*Pseudotsuga menziesii*) were planted on upper portions. Because the spur dike to the west of the public access path is no longer a structural dike, fir and spruce trees were planted on the dike top. Four Douglas firs also were planted on the dike segment (also no longer structural) along Union Slough, in a reed canarygrass-dominated area between areas of extensive blackberry cover.

Follow-up inspections of the success of riparian plantings were conducted during through 2002. Initial inspections (May and June 2001) indicated a very high rate of survival of rooted plants purchased from the nursery and leaf formation on the great majority (about 50 percent) of unrooted cuttings. However, by August 10, 2001, dry summer weather had led to substantial losses of nursery plants, particularly those placed on the top of the dike. Leaves that had formed on cuttings had shriveled and died, and only about 10 percent of the cuttings retained any green leaves. By December 2001, most (about 95 percent) of the cuttings appeared to have died; many of these cuttings had significant root formation but appeared to have succumbed to the drying of the generally clayey soils of the dike. Also, significant colonization of the dike by Scot's broom and blackberries was noted and many of these plants have been pulled from the top and water side of the dike throughout 2001 - 2002. A subsequent planting of willow stakes cut at about river mile 11 in March 2002 had somewhat higher survival to late summer, but many of these plants succumbed to the unusually dry autumn of 2002. Finally, a volunteer Boy Scout Eagle Scout project planted about 50, well-rooted Sitka spruce, alder, cottonwood, and willows along the north shore of the site in October 2002. Observations in early 2003 suggest a relatively high survival of these plants.

Below the high tide line, some colonization of the upper mudflats by marsh species such as brass buttons (*Cotula coronopifolia*), bentgrass (*Agrostis alba*), and fat hen saltbush (*Atriplex patula*) was evident beginning in May 2001 and colonization continued to expand through the summer. By early August, these marsh plants had achieved near 100 percent cover over a 3- to 4-m-wide band along much of the upper intertidal slope of the eastern dike and in large patches along the northern dike.

Vegetation Monitoring

In August 2002, a quantitative measure of marsh area was calculated from an AutoCAD drawing based on field measurements of areas supporting over 25 percent cover of saltmarsh species and found to be approximately 3.5 acres (Figure 2). Only small areas of the shoreline along the north and west dikes exhibited less than 25 percent cover in the saltmarsh zone (between +8 and +14 feet MLLW). For those areas with greater than 25 percent cover, dominant species and total cover were estimated. Based on these observations, seven vegetative assemblages were identified within the saltmarsh. The species composition of these assemblages was not always different; rather, differences in some cases appeared related to successional stages (Table 3). It is anticipated that over time these areas will blend together to become more homogeneous (i.e., fewer vegetation types).

The highest percent cover was observed along the eastern shoreline. Dominant species were brass buttons, toad rush (*Juncus bufonius*), bentgrass, and reed canarygrass (*Phalaris arundinacea*). Brass buttons and toad rush were common along the lower marsh areas along all shorelines. Bentgrass was primarily observed along the eastern shoreline along the upper edge of the saltmarsh. Lyngby's sedge (*Carex lyngbyei*) was colonizing lower mudflat elevations throughout the northern portion of the site, but densities did not meet the 25 percent cover threshold. Reed canarygrass dominated the supralittoral habitat on the western shoreline along the inside edge of the dike. The southernmost section of the restoration site (approximately 400 feet of the southern SM-5 and SM-6 areas) consists of a complex of islands and small channels or pools. This end likely remains inundated for longer periods of time with waters of lower salinities. Cattails (*Typha latifolia*) and hardstem bulrush (*Scirpus acutus*) were found only in saltmarsh zones 5 and 6.

Juvenile Salmonid Surveys

Limited fish monitoring was conducted at the Union Slough restoration site between late August 2001 and early January 2002 as part of a Corps bull trout monitoring study in the lower Snohomish River (Pentec 2002). Beach seine sets along the northern shore of the site were conducted biweekly to weekly for a total of 29 sets on 15 days over this August to January period.

Although the Union Slough site was created only 6 to 11 months before the beach seine monitoring, 13 fish species or families and Dungeness crab were observed in the site from late summer to early winter (Table 4). Salinities fluctuated greatly, dependent upon tide cycle and precipitation runoff, ranging from almost fresh water to 17 parts per thousand (Table 5). This wide range in salinities supported the presence of freshwater, estuarine, and marine fish species. Low-salinity estuarine species such as shiner perch, starry flounder, and Pacific staghorn sculpin dominated catch through the summer and fall, and into early winter. Most of these species were represented by juvenile life stages. A few juvenile salmonids were observed (chinook, coho, and steelhead), mostly in late summer and fall. Most of these fish were more than 100 mm in length, and probably represented yearlings. Several larger (173 mm to 260 mm) sea-run cutthroat trout were observed in the slough during the late summer and fall. Data from the rest of the Snohomish River Estuary indicate that these are likely inmigrating subadult fish (immature fish that outmigrated to rear in marine areas during the summer) that slowly move upstream through the estuary to overwintering areas near the head of tide (Pentec 2002).

Freshwater species, such as peamouth, were observed only during the late fall months when salinities were very low (<1 part per thousand). Similarly, species considered largely marine, such as Pacific herring, were observed only during periods of higher salinities (13.2 parts per thousand). Surf smelt, considered nearshore marine species, showed incursions into several areas of the lower river, including Union Slough.

Three sites along the north shore of the Union Slough restoration site were selected as part of a juvenile salmonid behavior study in conjunction with observations made at the Port of Everett's North Marina and 12th Street Waterway. Site visits were made six times between April 4 and June 19, 2002, and juvenile salmonids were observed at the Union Slough sites on two dates. On April 4, juvenile pink salmon 25 to 30 cm long were observed along the north shore of the site near Union Slough. One school of 1 to 10 fish demonstrated polarized, rapid movements and likely had been spooked offshore. On May 3, a school (11-100 fish) of juveniles, presumed to be chinook approximately 35 cm long, was observed along the center of the northern shore of the site. They were actively milling and heading west adjacent to the shoreline. Also on May 3, juvenile chum and chinook salmon were observed in schools of up to 100 fish moving into the site along the outer north shore. One school was swimming approximately 2 m from shore; another was near the root ball of a large log perched on the beach.

Juvenile Dungeness crab used the restored wetland during higher tide cycles for a relatively short period from late September through early October 2001. Collection of this species in more than two sampling events meets one of the original site success criteria of the mitigation plan (Pentec 1996).

Status of Mitigation Credits

The mitigation plan (Pentec 1996) was based on the policies and a salmon habitat model developed as part of the Snohomish Estuary Wetland Integration Plan (SEWIP; City of Everett et al. 1997). Policies of SEWIP governed the amount of mitigation required to replace the loss of the 9.4 acres of littoral habitat as a result of the Stage 1 MTI and the compensation required (deductions from credits available) for existing palustrine wetlands within the site. A total of 12.25 acres of the 19.3 acres of habitat created in the Union Slough site (area below ordinary high water or +14 feet MLLW) have been committed as mitigation for the Stage 1 MTI, leaving 7.05 acres remaining in the site to serve as advanced mitigation for future Port projects.

The Future

In Year 3 (2003; Table 1) quantitative monitoring of site use by birds and juvenile salmonids will be conducted along with measurement of epibenthic zooplankton standing crop. Quantitative monitoring of saltmarsh establishment will also be conducted in August 2003 (Table 1). Efforts to control invasions of the riparian zone by non-native species including Scot's broom, blackberries, and Japanese knotweed will continue. No contingency plans are included that require active intervention in the site should river processes gradually or suddenly change the nature of the site. The intent is that, once site success criteria have been demonstrated, the site will be left to evolve as dictated by those natural processes.

Summary

The Union Slough Restoration Project was completed with dike breaching in early February 2001. By April 2001, when the first outmigration of juvenile salmonids had begun, the mudflat already showed signs of a high productivity of microscopic plants and epibenthic crustaceans upon which juvenile salmonids feed. Large numbers of juvenile salmon were present throughout the spring of 2001 and 2002 and lesser numbers used the area into early winter. Shorebirds, such as dunlin, killdeer, and semipalimated plovers, also feed on crustaceans and were present during the first year following the dike breaching. Use of the site by both salmon and shorebirds is expected to increase as the site evolves to more closely resemble a natural mudflat and marsh ecosystem.

The new dikes constructed to protect the I-5 embankment from flooding were seeded with native grasses in early 2001 and planted with limited numbers of riparian (i.e., shoreline) trees and shrubs in April and May 2001. Areas of the site below the high water line began to develop productive saltmarsh vegetation which covered 3.5 acres of the mudflat by August 2002. Willow cuttings planted in early April had poor survival through the summer, presumably because of the onset of very dry conditions prior to formation of an adequate root system.

Although the primary goal of the project was to provide valuable habitat for juvenile salmonids, it was expected that many other species would benefit as well. A wide variety of animals, ranging from dunlin to Dungeness crab, have been documented using the site during the first years following breaching of the dikes, and several site success criteria have been met already. The site will be monitored until 2010 to document the production of invertebrate prey organisms and use by juvenile salmonids, other fish, Dungeness crabs, and shorebirds.

Results of monitoring to date confirm that breaching dikes that have isolated former tidal habitats from estuarine processes is an excellent approach to habitat restoration with a very high probability of success. While functions provided may not fully duplicate functions that existed in nature at the site, they can be expected to approximate some of those functions very quickly (e.g., Shreffler 1992) and to evolve at varying rates toward increasing levels of other functions (e.g., Simenstad and Thom 1996). Where significant land alterations have occurred behind the dikes (filling, leveling of natural contours), the course of site development can be influenced, at least initially, by grading to mimic anticipated site contours, especially channels and elevations suitable for development of desired vegetation types.

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Figures and Tables

Table 1. Monitoring Schedule

Union Slough Restoration Site	(Year 0) 2000	(Year 1) 2001	(Year 2) 2002	(Year 3) 2003	(Year 4) 2004	(Year 5) 2005	(Year 6) 2006	(Year 7) 2007	(Year 8) 2008	(Year 9) 2009	(Year 10) 2010
Construction											
Breach dikes		•									
Topographic survey	•					•					•
Inspections	•	• •	• •	• •	• •	• •	•	•	•	•	•
Saltmarsh establishment (August)			•	•		•		•			•
Juvenile salmonid use (April/May)				••		••		♦♦			••
Juvenile salmonid prey (April/May)				••		••		♦♦			••
Shorebird use (March/April/Sept)				• • •		• • •		♦ ♦ ♦			
Dungeness crab use (August)				•		•	♦				
Reports (March 15)		•	•	•	•	•	•	•	•	•	•

• = Milestones/mandatory monitoring
♦ = Optional or contingency monitoring

Table 2. Rooted Riparian Vegetation Purchased from Storm Lake Growers

Plant Species	Number	Type
Red alder (*Alnus rubra*)	30	Bare root
Redtwig (red-osier) dogwood (*Cornus sericea*)	20	Bare root
Pacific crabapple (*Malus fusca*)	10	1 gallon
Sitka spruce (*Picea sitchensis*)	20	1 gallon
Douglas fir (*Pseudotsuga menziesii*)	20	1 gallon
Red-flowering currant (*Ribes sanguineum*)	10	Bare root
Thimbleberry (*Rubus parviflorus*)	10	Bare root
Salmonberry (*Rubus spectabilis*)	10	Bare root
Black twinberry (*Lonicera involucrata*)	10	1 gallon
Pacific ninebark (*Physocarpus capitatus*)	20	Bare root
TOTAL	160	

Table 3. Saltmarsh Zone Descriptions as of August 5, 2002

Saltmarsh Zone	Length of Shoreline (feet)	Total Area >25% Coverage (Est. % Cover)	Dominant Species (% Cover)	Other Plant Species (Trace/Sparse)
SM-1: PP-1 toward PP-2 (Northwest corner)	100	2,732 sq ft (35% cover)	*Juncus bufonius* (30%)	*Carex lyngbyeii* *Juncus balticus* *Cotula coronopifolia* *Phalaris arundinacea* *Potentilla anserina*
SM-2: PP-2 to PP-3 (northern shore to tidal channel east corner)	450	20,855 sq ft (65-70% cover)	*Cotula coronopifolia* (20–45%) *Juncus bufonius* (20-35%) *Agrostis alba* (tr-15%)	*Eleocharis parvula* *Alisma plantago aquatica* *Polygonum* sp.
SM-3: northeastern shoreline	975	24,390 sq ft (50-65% cover)	*Agrostis alba* (20-50%) *Juncus bufonius* (15-20%) *Cotula coronopifolia* (10-20%)	*Eleocharis parvula* *Alisma plantago aquatica* *Polygonum* sp. *Carex lyngbyeii* *Alopecurus geniculatus* *Lilaeopsis occidentalis* *Alisma plantago aquatica*
SM-4: middle third of eastern shore	1,250	32,705 sq ft (70-85% cover)	*Cotula coronopifolia* (15-50%) *Agrostis alba* (20-55%) *Juncus bufonius* (15-30%)	*Juncus effusus* *Eleocharis parvula* *Polygonom* sp. *Alisma plantago aquatica*
SM-5: southeastern shoreline	700	27,109 sq ft (95-100% cover)	*Cotula coronopifolia* (20-60%) *Agrostis alba* (10-80%) *Phalaris arundinacea* (10-40%) *Scirpus americanus* (tr-10%)	*Typha latifolia* *Polygonum* sp. *Eleocharis palustris* *Juncus effusus* *Scirpus acutus* *Alisma plantago aquatica* *Ranunculus sceleratus* *Potentila palustris* *Carex lyngbyeii*
SM-6: southwestern dike area and “islands”	400	10,131 sq ft (60-80% cover near dike; 50-60% cover on islands)	*Cotula coronopifolia* (30-80%) *Phalaris arundinacea* (tr-50%)	*Typha latifolia* *Polygonum* sp. *Eleocharis parvula* *Juncus balticus* *Juncus bufonius* *Scirpus acutus* *Alisma plantago aquatica* *Ranunculus sceleratus* *Carex lyngbyeii*
SM-7: northwestern dike area	1,325	34,510 sq ft (30% cover or less)	*Cotula coronopifolia* (5-30%) *Phalaris arundinacea* (5-20%)	*Juncus bufonius* *Juncus balticus* *Eleocharis parvula* *Callitriche heterophylla* *Agrostis alba* *Carex lyngbyeii* *Atriplex patula* *Triglochin maritime* *Alisma plantago aquatica*
Totals	**5,200 ft**	**152,432 sq ft (3.5 acres)**		

PP = photopoint; tr = trace

Table 4. Beach Seine Monitoring Results at eh Union Slough Mitigation Site, August 2001 to January 2002

Species	Number of Fish	Dates Observed
ANADROMOUS SALMONIDS		
Chinook salmon, *Oncorhynchus tshawytscha*	4	9/11 – 10/2
Coho salmon, *O. kisutch*	3	9/11 – 11/15
Steelhead trout, *O. mykiss*	2	8/23 and 12/5
Sea-run cutthroat trout, *O. clarkii*	7	9/11 – 11/15
ESTUARINE SPECIES		
Shiner perch, *Cymatogaster aggregata*	1,808	8/23 – 10/26
Sculpin, Cottidae	42	8/23 – 12/5
Threespine stickleback, *Gasterosteus aculeatus*	20	8/23 – 12/5
Starry flounder, *Platichthys stellatus*	84	8/23 – 12/19
MARINE SPECIES		
Pacific herring, *Clupea pallasi*	6	1/4
Pacific sandlance, *Ammodytes hexapterus*	2	9/20 – 10/21
Smelt, Osmeridae	11	12/19
FRESHWATER SPECIES		
Peamouth, *Mylocheilus caurinus*	65	8/23 – 9/20
Yellow perch, *Perca flavescens*	1	12/5
INVERTEBRATES		
Dungeness crab, *Cancer magister*	19	9/20 – 10/10

Table 5. Salinity and Temperature Data Collected at the Union Slough Mitigation Site

Date	Temperature (°C)		Salinity (ppt)	
	Surface	1 meter	Surface	1 meter
8/23/01	--	--	--	--
9/11/01	16.8	16.5	12.9	13.5
9/20/01	17.0	17.0	9.0	9.0
10/2/01	15.0	15.0	12.8	9.1
10/10/01	11.2	11.8	12.0	17
10/17/01	10.2	10.2	2.2	2.2
11/9/01	7.0	7.0	5.0	9.0
11/20/01	6.8	4.0	0.5	0.9
11/29/01	6.0	6.0	2.5	2.5
12/5/01	5.5	5.5	2.0	2.0
12/12/01	5.0	5.0	<1.0	<1.0
12/19/01	4.5	4.5	<1.0	<1.0
1/4/02	6.0	7.0	3.8	13.2

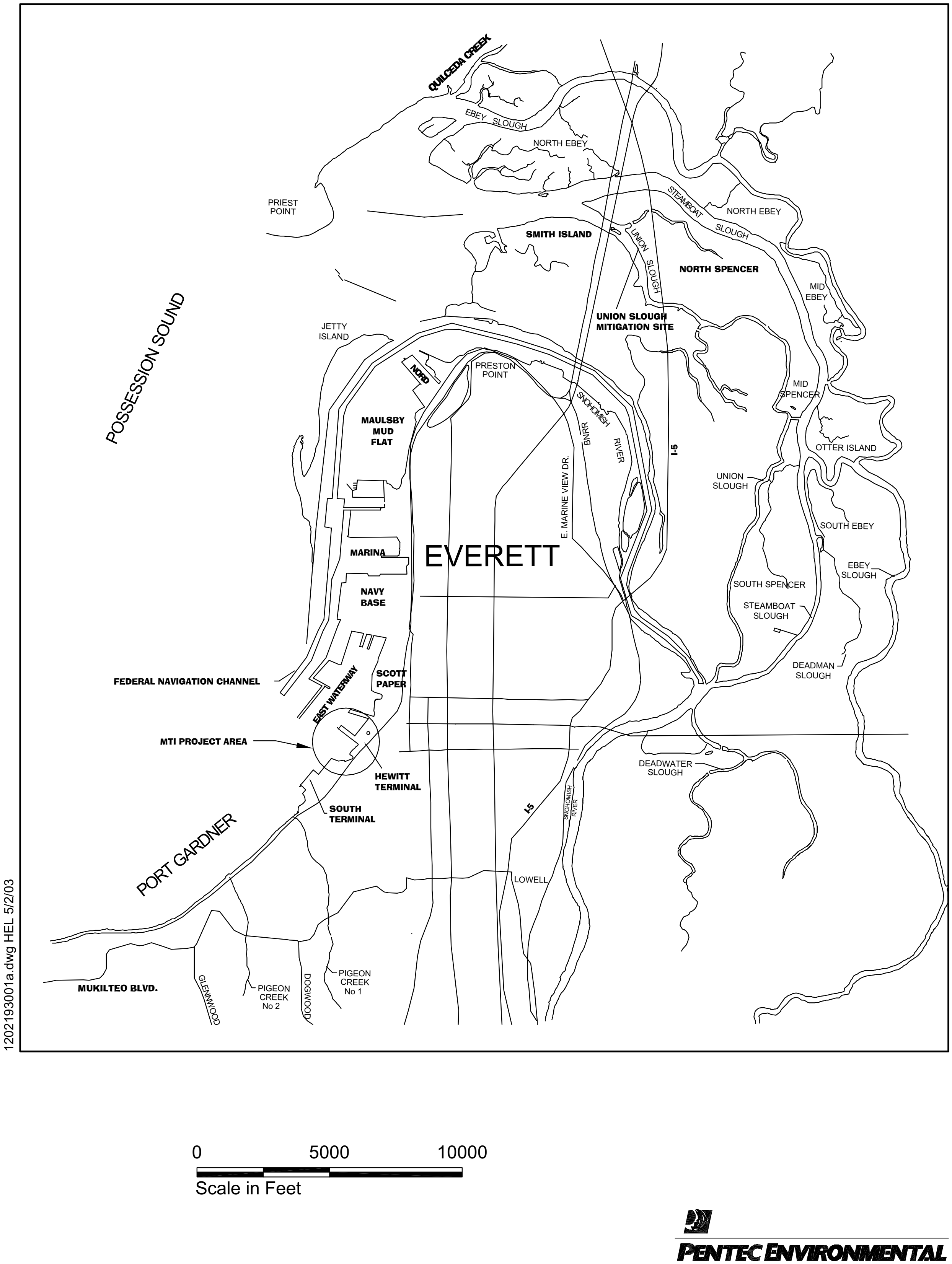

Figure 1. Location of Marine Terminal Improvements and Union Slough Mitigation Site

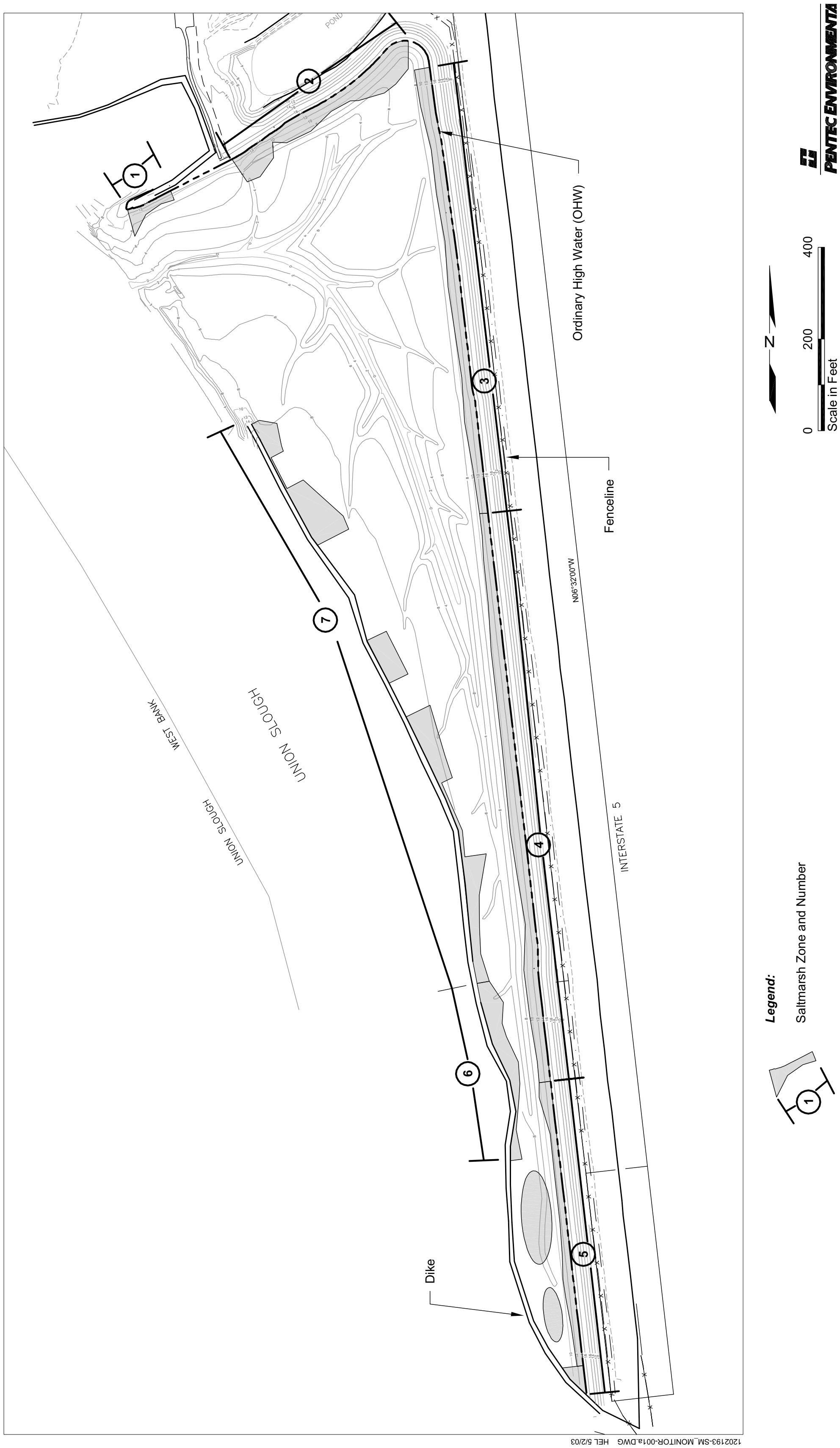

Figure 2. Site Contours and Saltmarsh Assemblages (August 2002)

Photo 1. Union Slough mitigation site, preconstruction

Photo 2. Union Slough mitigation site, post-construction

Photo 3. Union Slough east shore; photopoint 3 looking south; May 2001

Photo 4. Union Slough east shore; photopoint 3 looking south; September 2002